

## Biology and Immature Stages of Australian Ethmiid Moths (Gelechioidea)

Jerry A. Powell

Department of Entomological Sciences, University of California, Berkeley, CA 94720

**Abstract.** Biological data for 5 species of *Ethmia* are reported, *E. sphaerosticha*, *E. postica*, *E. thoraea*, *E. heptasema*, and *E. heliomela*, based on observations in New South Wales and Queensland in 1980-81. Their eggs are characterized, along with larvae and pupae of the first and last species. The larva and pupa of *E. hemadelpha* from Western Australia and the pupa of *E. nigroapicella* from Hawaii are described. Known or suspected food-plants of all seven are Boraginaceae.

Ethmiids are small, often brightly colored moths sharing a general similarity in superficial appearance throughout all faunal regions of the world. There are remarkable differences, however, in less obvious morphological characteristics of the adults, in biological traits, and in the eggs, larvae, and pupae. The group is distinct taxonomically and has been regarded as a family (Sattler, 1967; Common, 1970; Powell, 1973; Kuznetsov & Stekol'nikov, 1979) or a subfamily of the large cosmopolitan family Oecophoridae (Hodges, 1978). In species diversity, ethmiids are best represented in areas of seasonal drought, such as the thorn scrub of the northern Neotropical Region. Each species is restricted in larval foodplant preference, and in general *Ethmia* are dependent upon Boraginaceae and the closely related, primarily Nearctic family Hydrophylaceae (Sattler, 1967; Powell, 1973, 1980).

For its size, Australia has a depauperate ethmiid fauna, with only 14 species, but most of them are endemic, including some specialized forms (Powell, 1982). Among these, three species groups with differing male genitalia types exhibit striking similarity in these structures to Neotropical species groups that are known or believed to possess uniquely derived larval and pupal traits (*Ethmia*, Section II of Powell, 1973). Thus it was of considerable interest from a biogeographic viewpoint to discover whether the derived features of the immature stages in the New World are shared by Australian species.

During residence at the Division of Entomology, Commonwealth Scientific and Industrial Research Organization (CSIRO), Canberra, in 1980-81, I was able to obtain some information on the biology of 5 species and received material collected by K. T. Richards of Perth, W.A.,

representing a sixth species. As a result, some data on oviposition behavior are summarized, and larval and pupal descriptions are given for 3 species. With existing descriptions of *Ethmia nigroapicella* (Saalmueller) (Moriuti, 1963; MacKay, 1972; Zimmerman, 1978), these data provide a representative picture for 4 of 5 Australian species groups outlined elsewhere (Powell, 1982).

## Techniques

Methods of handling living material were generally similar to those given previously (Powell, 1971). Moths were confined for oviposition either in plastic tubs ca. 25 x 25 x 13 cm with a cardboard floor and nylon stocking mesh ceiling, or in 10 x 1.5 cm glass or plastic petri dishes with nylon lining the lid. Newly hatched larvae were reared on branchlets of foodplant in plastic pill boxes or small refrigerator boxes; larger larvae were housed in plastic tubs or polyethylene bags lined with paper towels. Full grown larvae were offered folded paper towels and layers of soft corrugated cardboard, owing to the preference among many Holarctic *Ethmia* for burrowing into soft material for cocoon construction.

Rearing was conducted in uncontrolled laboratory temperatures, which varied widely. During hot periods larval lots were housed in better insulated, cooler rooms to deter disease. Nonetheless two larval groups became diseased; a common problem with communal rearing of *Ethmia* in North America (Powell, 1971).

Hostplant associations have been determined for three species, *E. hemadelpha*, *E. sphaerosticha*, and *E. heliomela*, by discovery of larvae in the field. For others, attempts were made to elicit oviposition response by providing Boraginaceae suspected to be hostplants, by correlation of the geographic distribution of moths and plants according to records in the Australian National Insect Collection (ANIC) and Herbarium Australiense, CSIRO, Canberra. Plant samples presented to moths or caterpillars were obtained from the National Botanic Garden, Canberra, or commercial nurseries.

Scanning electron micrographs were executed by Barry Filshie, using living eggs on leaf substrate. Ethmiid eggs seem to resist distortion due to the vacuum when processed *in situ* on leaves and need not be metal coated. In preservation, larvae were killed in hot water just below the boiling point. After sufficient distension occurred, they were transferred to Kahle's solution and ultimately to 95% EtOH. Measurements in larval and pupal descriptions were made by a micrometer disc at 6.3 to 20X magnification, of eggs at 20X to 40X. The number of individuals measured or observations upon which statements are based is indicated (n).

Consistent biological features of ethmiids have been summarized elsewhere (Powell, 1971, 1973) and are not repeated here. An exception to the oviposition pattern shown by Nearctic *Ethmia* occurs in two Australian

species, *E. heptasema* and *E. heliomela*, which usually deposit eggs in small clusters. In all previous records for the genus, and the 3 other Australian species I observed, oviposition is single. The eggs of *E. sphaerosticha* are flat, unlike any others known in the genus. None of the 4 species for which late instar larvae and pupae are known possess any of the uniquely derived features characteristic of *Ethmia* Section II of the New World.

*Ethmia sphaerosticha* (Meyrick, 1886)

This species is unique among all known ethmiids for the enlarged antennae with expanding scale brushes in the male (Common, 1970: 814, Fig. 36.27k). The egg and pupal anchoring mechanism also differ from any previously described in the genus. *E. sphaerosticha* occurs in the rain forests of eastern coastal mountains, disjunctly, in northern Queensland and from southern Queensland to southern New South Wales (Powell, 1982).

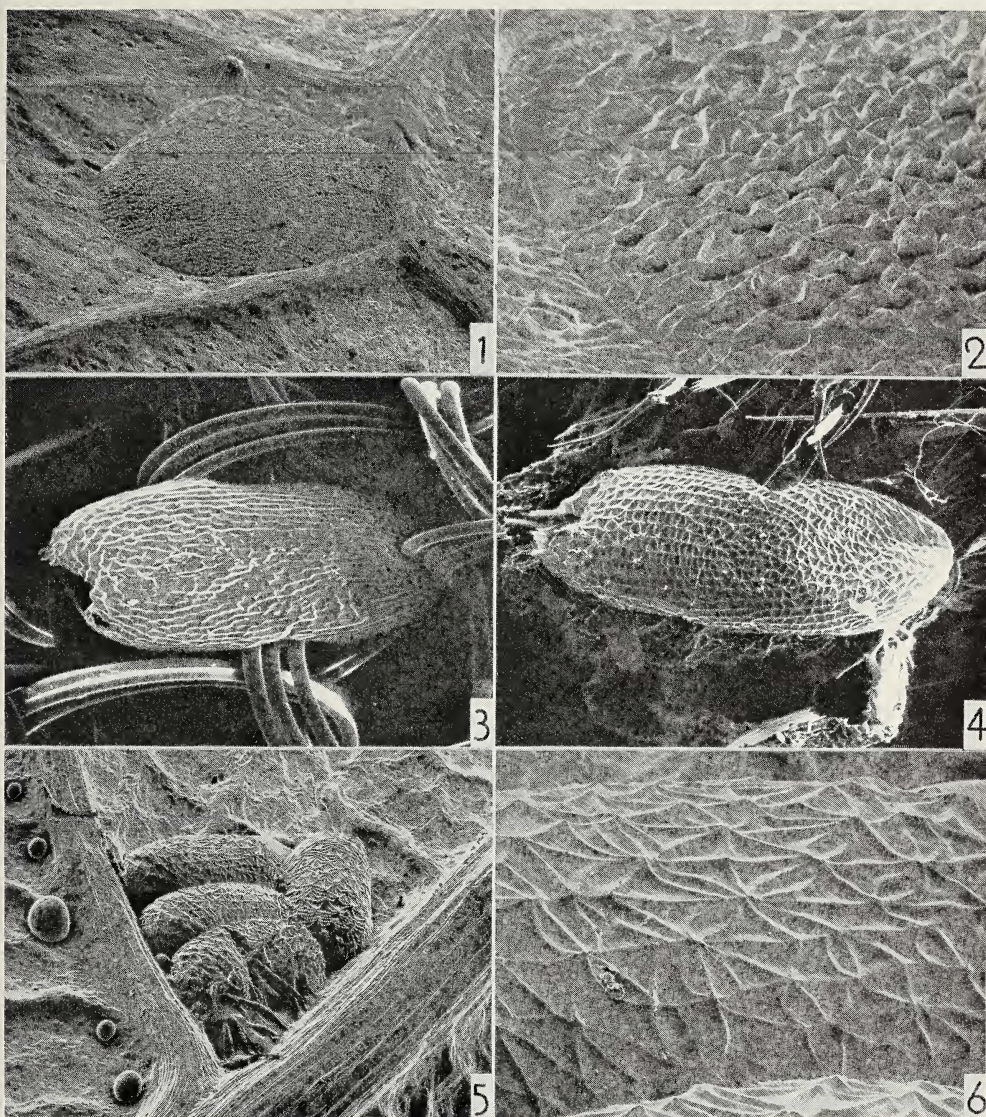
*Adult behavior*.—Although they possess relatively small eyes (eye index 0.85; see Powell, 1973:8), the moths are nocturnal, and both sexes are attracted to lights. One male was taken flying at 1715 hrs, before sunset, but in laboratory confinement moths were diurnally inactive. Field-collected females (80M25, 81A105, A113, A121) survived 2-9+ days ( $\bar{x}=6$ , 7n). Two failed to oviposit, but the others deposited 25-30 eggs each. One female laid 10 eggs on day 7 of confinement, although only water was provided as nourishment. All eggs were deposited singly.

Females were housed in a plastic bag and plastic tub with a bouquet of *Ehretia acuminata* R. Br. in bloom (80M25) or in petri dishes with *Ehretia* leaves. About 50% of the eggs were placed on leaves, almost always on the undersides, irrespective of whether leaves were presented to the moths upsidedown or topside up, or as an upright bouquet. Only two eggs were laid on the upperside of a leaf in crevices. The remainder were placed on plastic or glass surfaces above the plant. None was laid on flowers, fruit or stems, or on the nylon mesh that is often selected by *Ethmia* (Powell, 1971).

*Egg*.—The eggs are flat, like those of tortricids, with both overall shape and surface sculpture (Figs. 1, 2) unlike those of any other described ethmiid. They ranged 1.17-1.40 X 0.67-0.80 mm in length and width and were weakly convex, less than 0.25 mm thick. Eggs took the form of the substrate, and their outline was highly variable. To the unaided eye the eggs appeared milky, and the color did not change during development, which was faster than in any other microlepidopteran I have observed. Only 5-6 days (80M25) or 4-5 days (81A113) were required until hatching.

*Larva*.—Newly hatched larvae were whitish, semi-translucent, including the head capsule (HC). They fed only on undersides of leaves, skeletonizing the surface and cutting tiny holes through the full thickness. After feeding





Figs. 1-6. Eggs of Australian *Ethmia*: 1, egg *E. sphaerosticha* on underside of *Ehretia acuminata* leaf (x30); 2, *E. sphaerosticha*, closeup of chorion sculpture (x235); 3, eggshell *E. posuca* on nylon mesh (x42); 4, eggshell *E. thoraeca* on leaf of *Cynoglossum australe* (x45); 5, egg clutch *E. heptasema* on underside of *Ehretia acuminata* leaf (x33); 6, *E. heptasema* closeup of chorion sculpture (x200). Magnifications approximated to published size.



2-3 days, larvae appeared slightly greenish due to the gut contents and were extremely well camouflaged on the leaf surface. By the eighth day all larvae were in the 3rd instar, continuing to feed on the lower surfaces of leaves. Later instars also fed from beneath leaves, eating large holes but not feeding at the margins. They rested under flat webs on older leaves, migrating out to feed on newer foliage (in laboratory conditions). The flat webs were used for moulting by all instars, and seemed to be constructed only for this purpose. In the field (81A107) and lab (81A113) most moulting webs of antepenultimate and penultimate instars were constructed on uppersides of leaves no longer used for feeding or on container walls.

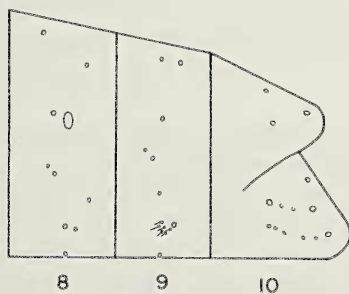
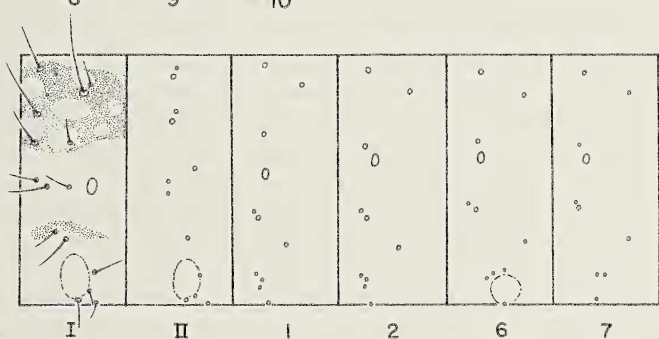
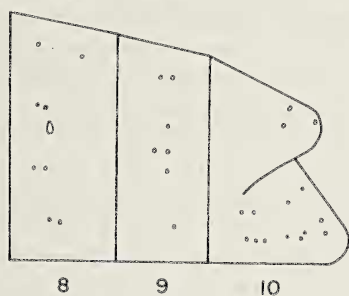
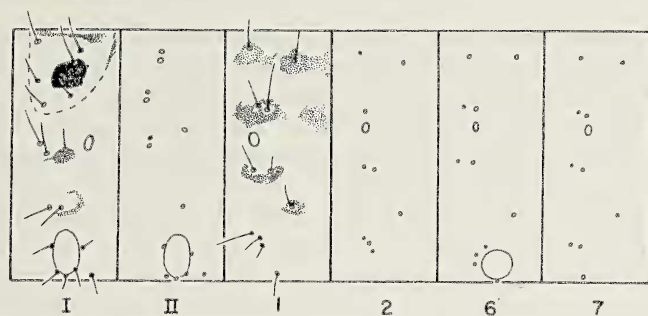
There were 6 discrete instars according to HC measurements (mm):

I = 0.31 (unfed) to 0.33 (shed HC); II = 0.41 to 0.51 (shed HC's); III = 0.98 to 1.02 (shed HC's); IV = 1.19 to 1.23 (pres. larvae); V = 1.42 (pres. larva) to 1.47 (shed HC); VI = 1.76 (starved) and 1.96 (preserved) to 2.10 (living).

The first 3 instars were whitish with no integumental markings. A small black spot appeared on each frontal lobe in IV, along with tiny spots on D1 pinacula. In instar V larvae were cream colored, their spots increased in size, and sometimes small crescents were present below D2 and L pinacula. Extensive, variable black markings characterized the yellowish final instar (Fig. 7).

Growth was more rapid than that recorded for any North American ethmiid (Powell, 1971). The final instar was reached on day 15-17 following egg hatch, and full grown larvae appeared ready to pupate by day 19-24 (81A113), despite having fed on *Ehretia* which had been refrigerated 25-35 days. Those in lot 80M25 were not given additional leaves after day 7, owing to my absence on a field trip, yet nearly all reached the final instar and were starved or diseased by day 18. None was reared from egg through pupation, but those collected as last instar larvae produced adults 18-24 days following collection (80L47.1, 81A107). Thus the entire development from egg deposition to emergence can occur in 40-46 days.

*Final instar larva*.—Length 15.8 to 18.3 mm (starved individuals). *Head*: HC width 1.76 (starved) to 2.10 mm. Setation typical for the genus (e.g. MacKay, 1972); A<sup>1</sup>, A<sup>2</sup>, A<sup>3</sup> and L<sup>1</sup> nearly on a straight line, with A<sup>2</sup> only slightly displaced posteriorly. Adfrontal sutures extending to cervical angle but abruptly approximate well below, adfrontal areas extremely narrow above P<sup>2</sup>. Cream colored, broadly blotched with black across middle and narrowly along ventral border. *Body*: Primary setal arrangements of thorax and abdomen as in fig. 7. Pinacula of D, SD strongly raised. L1 and L2 on abdomen widely separated, especially on A1, and nearly on the same plane. Sclerotized depressions associated with spiracles or thoracic leg setae absent. No secondary setae except the usual gelechioid lower series of anal proleg. Integument yellowish or cream



Figs. 7, 8. Setaal maps of *Ethmia* larvae, Roman numerals refer to thoracic segments, arabic to abdominal: 7, *E. sphaeorsticha*; 8, *E. hemadelpa*.



colored, variably mottled with black, often more extensively than indicated in fig. 7. Crotchets of abdominal prolegs irregularly biordinal, in a mesoseries, 26-28; anal leg crotchets similar, 24-26.

This is the only species of *Ethmia* known to lack secondary setae of the abdominal SV groups, including both the prolegs and A9. Fully fed larvae normally exceed the size range given.

*Pupa* (fig. 10).—Length 10.3-13.0 mm (4n). Head without projections, with a deep groove mesad of each antennal base, lined mesally and anterolaterally with dense patches of golden setae (fig. 11). Antennae and wings extended to posterior  $\frac{1}{3}$  of A5. A5 dorsally, A6-A7 dorsally and ventrally movable by deep intersegmental clefts. Dense, rust-orange, setaceous areas around spiracles of A2-A6, on sides and posterior edge of A5-A6, all exposed surfaces of A7-A9, and dorsum of A10 (fig. 12). Spiracles small, of uniform size on A2-A8, closed on A8. Anal legs represent by raised areas, not exceeding anterior edge of A9, densely covered with hooked setae.

The setaceous grooves of the pupal head (fig. 11), which have not been observed in any other ethmiid, are well developed in both sexes. Evidently they are not homologues of the modified male antennae. The anchoring mechanism restricted to A9, without free anal legs, is a unique feature among described *Ethmia*. It resembles that of certain Stenomatinae (Fracker, 1915), and it may represent the ancestral state for ethmiids.

In the laboratory cocoons were constructed in folds of paper toweling or in lumens of corrugated cardboard. They were moderately dense, opaque, about 18 mm in outside length and had a smooth interior cell about 14 x 4 mm, without the loose mesh known in some *Ethmia*. Normally *Ehretia acuminata* is a rain forest tree with its canopy high above the ground. At the Bunya Mountains, however, I found one tree in sparse natural woods with penetrating sunlight, so that the lowest limbs could be examined. The lower canopy contained many dead branches, most of which had hollow centers, probably the result of beetle and aculeate Hymenoptera burrowing. Splitting of a random sample of 20 branches 5-10 mm in diameter produced 2 old cocoons of *E. sphaerosticha* (determined by larval exuvium color and pattern of pupal shell setaceous areas). Both had appropriated abandoned borings in 1 cm sticks.

Nearctic ethmiids are known to wander from hostplant foliage to seek shelters or burrow into soft substances for pupation (Powell, 1971, 1973: 39). Considering the intermittently wet conditions of rain forest floor litter, pupation above the forest floor would seem to be selectively advantageous, and appropriation of abandoned holes in the canopy branches may be the preferred cocoon site for *E. sphaerosticha* and other tropical *Ethmia*.

The duration of pupation was relatively long, in contrast to the rapid larval life. One male emerged 16 days following initiation of cocoon

construction (80L47.1); another emerged 19 days after the larval collection.

*Natural enemies*.—Most of my rearings were from eggs laid in the lab, precluding parasitoids, but among 6 larvae collected from *Ehretia*, 2 were parasitized by Braconidae and Tachinidae (81A107). An undersized penultimate larva collected 6 January in an old shelter failed to feed, and 6 days later a braconid larva emerged and spun a cocoon, leaving a hole in the intersegmental area of abdominal segments 4-5. The *Ethmia* larva remained active another day without feeding, before it was preserved. It is interesting that larvae of *E. arctostaphylella* (Wlsm.) in California displayed this same behavior in response to parasitoid feeding and emergence by *Apanteles* (Braconidae), which emerged from the side of the 3rd abdominal segment (Powell, 1971: 46).

The tachinid developed its puparium within the pupal shell of *E. sphaerosticha* and emerged 6 days later than a male *Ethmia* that had been collected as a last instar larva at the same time. One of the two cocoons discovered in hollow *Ehretia* twigs at the Bunya Mountains also had an abandoned tachinid puparium inside the *Ethmia* pupal shell.

*Volitinism*.—Collection records of adults suggest two or more generations per season, with most records in November and January to March (Powell, 1982). Full grown larvae were present at Mt. Keira in late November, adults in late December, 1980. Final instar F<sub>1</sub> larvae from the latter (80M25) were preserved in mid-January and presumably would have produced adults by early February. *Ethmia sphaerosticha* has been collected at Mt. Keira as late as early April (1953 and 1964, V. J. Robinson); thus, it is possible that 4 flights occur: late October, mid- to late December, late January to mid-February and late March to early April. Overwintering presumably occurs as a pupa in diapause, as is known for multivoltine Nearctic species (Powell, 1971, 1974).

*Collection data*.—Mt. Keira, Wollongong, N.S.W., larvae 25/26 Nov. 1980 (JAP80L47.1), females (MV light) 20 Dec. 1980 (80M25); Bunya Mts., Q., females 5 Jan. 1981 (bl) (80A105), larvae 6/7 Jan. 1981 (81A107), female 7 Jan. 1981 (bl) (80A113); Whian Whian State Forest, NE of Lismore, N. S. W., female (bl) 12 Jan. 1981 (81A121).

*Ethmia postica* (Zeller, 1877)

This is the most widespread ethmiid on the Australian continent, occurring in interior areas from northwestern and south central W. A. to western Queensland, N. S. W., and Victoria (Powell, 1982).

*Adult behavior*.—The moths are nocturnal. Virtually all collections have been made at lights, and females confined in the lab were inactive during daylight hours. Eight females were caged in late September and October 1980, but dissections showed 5 of 6 salvaged to have been unmated. The other was mated and deposited 90 fertile eggs (80J112.3) during a 12 day period beginning 3 days following confinement. Water was supplied, and



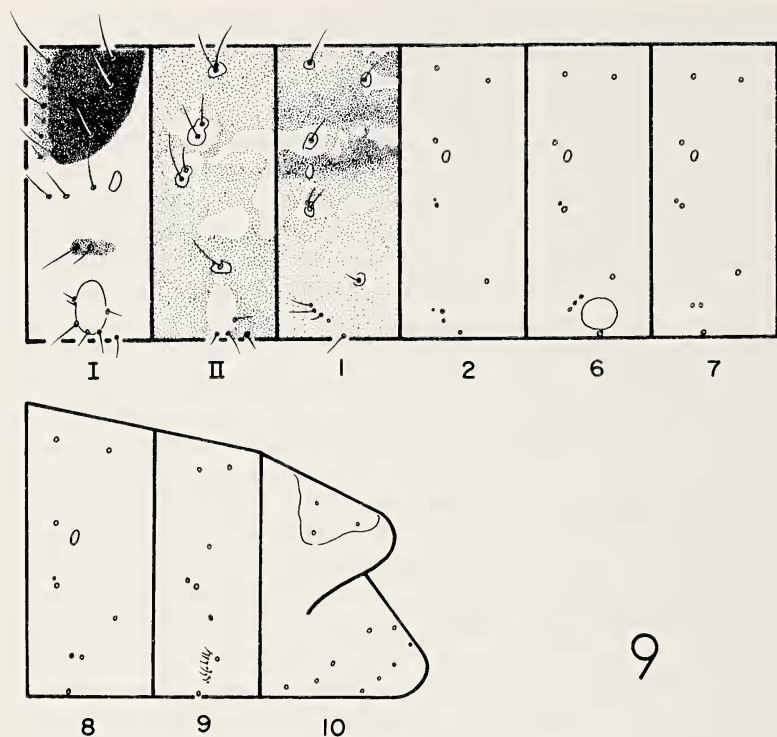


Fig. 9. Setal map of *Ethmia heliomela*. Shading depicts heavily marked form.

potential foodplants had flowers and aphids rendering copious honeydew, which may have been used by the females as nourishment. Unmated females survived 6-21 days ( $\bar{x} = 13.5$ , 7n) in captivity and the gravid female 23 days, the first 4 in refrigeration.

Various plant samples were presented including Boraginaceae: native *Cynoglossum australe* R. Br., *Ehretia acuminata*) and exotic (*Lithospermum prostratum* Loisel., garden *Myosotis*, *Echium vulgare* L.); Scrophulariaceae: (*Hebe diosmifolia* R. Cunn., *Veronica formosa* R. Br. and *V. calycina* R. Br.); and Fabaceae (*Westringia fruticosa* Druce). None elicited oviposition response except by the one female, which was offered *Lithospermum* and *Myosotis*, to which *Ehretia* (drying) was added on day 2, and *Veronica* on day 5. The first 6 eggs, deposited on day 3 or 4, were placed on *Myosotis* and *Lithospermum* nested in plant hairs in the fashion characteristic of many Nearctic *Ethmia* (Powell, 1971). Nearly all subsequent eggs were poked into the nylon mesh, a substrate also preferred by captive ethmiids in California.

Only 19 eggs were produced up to day 11 of confinement at room

temperature (16 days following collection); 79% of the eggs were deposited in days 12-18, 22 of them (24% of the total) during the last night the female was alive.

*Egg*.—The eggs were cylindrical with rounded ends and had conspicuous chorion ridges arranged in parallel rows, similar to those of Holarctic *Ethmia* (fig. 3). Those deposited in nylon mesh ranged 0.69 X 0.36 mm to 0.73 X 0.45 mm in length and width and were about as thick as wide, varying in details of form with irregularities of their enmeshment. Eggs were white with a pearly sheen when fresh, turning yellowish during development, which required 10-11 days at intermittently cool room temperatures.

*Larva*.—Newly hatched larvae were offered various combinations of foliage terminals of *Myosotis*, *Lithospermum*, *Echium*, *Cynoglossum*, and *Veronica*, during a 15 day period. Several fed for a few days on leaves of *Myosotis*, where they were positioned against container sides, but available plant material was deteriorating, and none of the larvae reached the second instar. Buds and leaves of *Lithospermum*, *Echium*, and *Cynoglossum* were densely hirsute and appeared to present insurmountable physical barriers to unfed larvae. Repeated attempts to elicit feeding in open flowers or artificially opened buds, failed; this is the feeding site of several Nearctic *Ethmia* that depend upon hirsute borages (Powell, 1971).

*Possible Hostplant Association*.—*Ethmia postica* females were collected near Queanbeyan, N. S. W., on the southern tablelands near the A.C.T. border. Although I.F.B. Common had never taken this species during 9 season sampling at the site, 18 individuals (11 ♂, 7 ♀), mostly in fresh appearing condition, were collected during a 4 night sequence. As a result it was assumed that some locally growing native or introduced Boraginaceae must have been the source; *Cynoglossum australe* and *Echium vulgare* were the most likely suspects according to the A.C.T. Flora. Later, however, when I had summarized the distribution of *E. postica* (Powell, 1982) and compared records of Boraginaceae in the Herbarium Australiense, *Halgonia cyanea* Lindl. emerged as a possible hostplant. This species, a low shrub of sand dunes and mallee scrub on sand, has a general distribution comparable to that of *E. postica* but is not known to extend east of the Great Dividing Range. Thus several peripheral southeastern records for *E. postica* are outside the range of this plant. Because these records are temporally sporadic, such as at Queanbeyan, at Black Mountain, A.C.T. (6 moths in Sept.-Oct., 1962, 1965, 1968 during a 15 year light trapping survey), and in southern Victoria (one specimen in the Gooding collection from Moe, where Gooding collected for many years), it is possible that they originate from passive movement of individual moths to cismontane areas from the interior via storm front airstreams. The likelihood of 18 individuals appearing at one MV light following such movement seems low, yet the fact that 5 of 6 females were unmated lends



credence to such a hypothesis. Normally female ethmiids are mated when attracted to lights, but it is well known that migrations of noctuids involve sexually immature adults (e.g. Common, 1954; Fox, 1978). Moreover, Fox has documented migration of many Lepidoptera across the Tasman Sea via storm front airstream movements to the southeast, particularly in October. While most of his records are for larger, strong flying moths and butterflies, the arctiid, *Utethesia pulchelloides* Hamps., seems to be weak flying to the human observer and also feeds on low growing Boraginaceae (McFarland, 1979). *Utethesia* was taken in numbers in New Zealand (9 specimens in one light trap, others at stations along a 400 km band of the west coast) during a 2 night period following passage of a front. Back trajectories calculated on meteorological data showed the likely origin of such moths to have been coastal southern Queensland or northern New South Wales 60 hours previously, a far greater distance than *Halgania*-associated insects would need to migrate to reach the Canberra area.

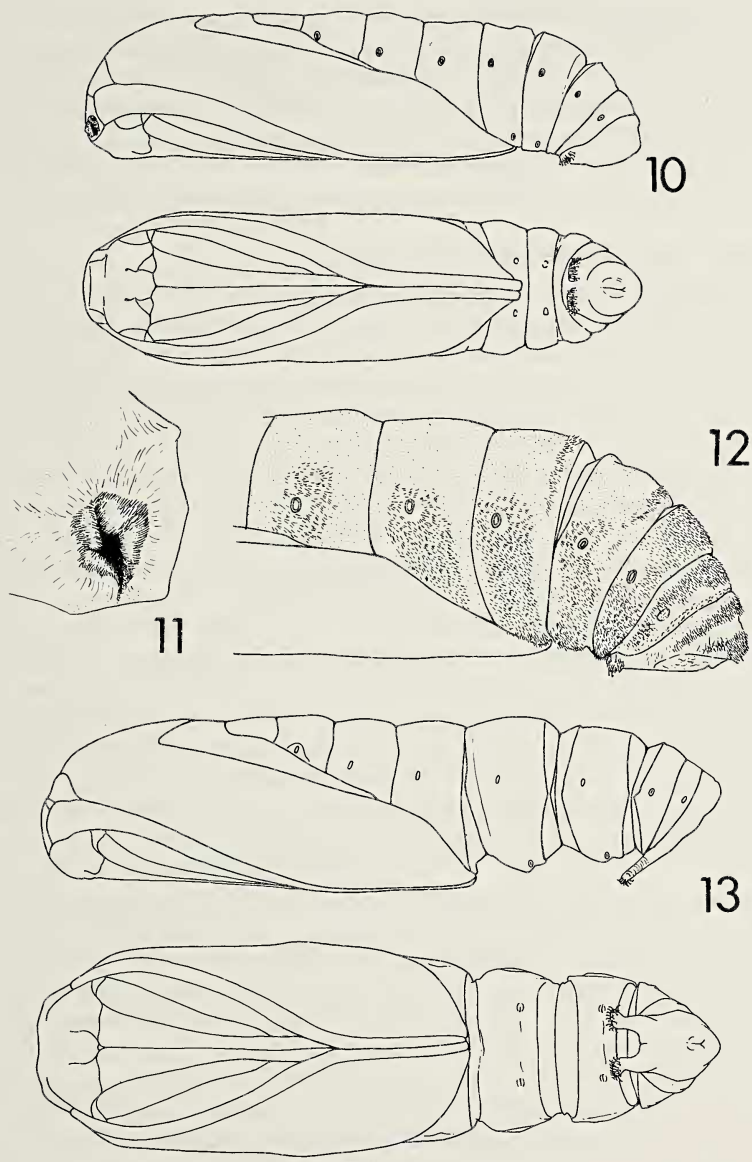
*Collection data*.—3 km NE Queanbeyan, N. S. W., 28 Sept. to 1 Oct. 1980 (MV light I.F.B. Common and J. Powell) (JAP80J112); same data 12 Oct. 1980 (80K124).

*Ethmia hemadelpha* (Lower, 1903)

A northern species, *E. hemadelpha* is widespread from west central Western Australia to the coastal mountains of southeastern Queensland (Powell, 1982). It was reared in 1962 by K. T. Richards at the Kimberley Research Station, W. A., from *Ehretia saligna*. The foodplant record was reported by Common (1970), at that time the only known host of an Australian ethmiid.

*Final instar larva*.—Length 18.6–22.2 mm (2n). *Head*: HC width 1.57–1.62 mm. Setation as in other *Ethmia* (e.g., Mackay, 1972). Adfrontal sutures extending to cervical angle, adfrontal areas abruptly attenuated posteriorly. Pale amber colored, mottled with rust except in stemmatal area. Primary setal arrangements of thorax and abdomen as in fig. 8. SD1 directly dorsad and well separated from the spiracle on A1, anterodorsad and approximate to spiracle on A2–8. SD2 lacking on abdomen. Sclerotized depressions associated with spiracles or with thoracic leg setae lacking. Secondary setae lacking except a cluster of 4–6 translucent, fine setae anteroventrad of SV on A9 (apparently missing on one individual). D area white; SD mostly rust colored (on preserved specimens) with round, white spots. The raised pinacula darker; L area whitish below spiracle, which is included in rust blotch of SD pinaculum on A2–8; SV area lightly tinged with rust, V pale. Crotchets of abdominal prolegs in a mesal “penellipse” (ca. half circle), irregularly biordinal, 22–28; anal prolegs crotchets irregularly biordinal, 24–26.

*Pupa* (fig. 13).—Length 10.2 mm (1n). Head without projecting structure. Antennae and wings extending to posterior margin of A4. A5–7 movable by



Figs. 10-13. Pupal characteristics of Australian *Ethmia*: 10, *E. sphaerosticha* pupa, lateral (upper) and ventral (lower) aspects; 11, *E. sphaerosticha*, lateroventral portion of frons (dorsum at top), showing detail of antennal pit; 12, *E. sphaerosticha*, abdominal setation; 13, *E. hema-depha* pupa, lateral (upper) and ventral (lower) aspects.



deep intersegmental clefts and lateral condyles. Raised areas posterior to spiracles on A3-A6 bearing dense patches of short setae which extend below spiracles in slight depressions. Anal legs well developed, boot-shaped, with dense clusters of hooked setae distally. A10 with a group of 6 blunt, nonhooked setae.

*Collection data*.—Kimberley Research Sta., W. A., 7 Oct. 1962, ex *Ehretia saligna* (K. T. Richards); associated reared adults examined.

*Ethmia nigroapicella* (Saalmueller, 1880)

Originally described from Madagascar, *nigroapicella* is widespread in the Indo Australian and Oriental Regions, from Madagascar to the Seychelles, India, Burma and the islands of New Guinea, Philippines, Fiji, Samoa, Ryukyu, Formosa, and it is well known (as *E. colonella* Walsingham) in Hawaii, where it is presumed to be introduced. The species reaches the northernmost extremities of Australia, on the Wessel Islands and Cobourg Peninsula, N. T. and Sue Island in the Torres Strait, Queensland (Powell, 1982). The Australian specimens are smaller and display minor morphological differences from that reported elsewhere for *nigroapicella*, and confirmation of the assignment of populations on the northern islands to *nigroapicella* must await study of further material.

*Foodplants*.—A notable defoliator of *Cordia subcordata* Lam. and occasionally feeding on *C. sebestena* L. in Hawaii (Swezey, 1944; Zimmerman, 1978), *nigroapicella* is also recorded from *Ehretia* sp., deduced to be *E. dicksoni* var. *japonica* Nakai, by Sattler (1967), and from *E. buxifolia* Roxb. and *Cordia* in Japan (Moriuti, 1963). Fletcher (1933) recorded *E. laevis* Roxb. in India, and *Cordia subcordata* was listed as the host in the Seychelles (LeGrand, 1965). Among these Boraginaceae, *Cordia subcordata* occurs in the Australian areas where *nigroapicella* is known.

*Larva*.—The last instar larva has been described from Hawaii by MacKay (1972) and Zimmerman (1978). The full grown caterpillar is brightly colored, black with light yellow DL lines and irregular light yellow spots including the lateral row above the spiracles, and is characterized by numerous secondary setae in the D, DL, L and SV groups, particularly on the thorax, differing in this respect from the other Australian *Ethmia* described here.

*Pupa* (figs. 14, 15).—General aspects described by Zimmerman (1978), who included an outline drawing by MacKay of the ventral aspect. In order to compare more subtle features of setation and spiracles with the other species, the pupa is further characterized as follows:

Length 9.6-10.1 mm (2n). Head without projecting structures. Antennae and wings extended to proximal one third of A5. A5-7 movable by deep intersegmental clefts and lateral condyles. Spiracles of A3-A7 situated on irregular raised ridges, followed and subtended by dense patches of golden setae; A5-A7 sparsely setate on anterior half below the spiracular

patches, spiculate posteriorly (fig. 15). Anal legs well differentiated, tapering, with distal margin slightly broadened, bearing dense clusters of hooked setae. A10 without true cremaster setae.

*Collection data.*—Hawaii: Volcanos Natl. Park, Kamoamoa, 30 March 1981, r.f. *Cordia subcordata* (F. G. Howarth); associated reared adults examined.

*Ethmia thoraëa* Meyrick, 1910

A member of the *Nigroapicella* Group (Sattler, 1967; Powell, 1982), *thoraëa* is related to several tropical rain forest species to the north. Its range, however, is broader than that of rain forests, from the north coast of Queensland to coastal N.S.W. in the Illawarra District, and inland at Cunnamulla, Q., and Mt. Kaputar, N.S.W. There are discrete spring and fall flights. Larvae of a related species, *E. nigroapicella* (Saal.) feed on *Cordia* and *Ehretia* in India, Japan and Hawaii (Sattler, 1967).

*Adult behavior.*—This and related species are believed to be strictly nocturnal, despite their brightly colored, aposematic-appearing hindwings and abdomen. One female confined in a petri dish lived 12 days during mid-January. She was fresh appearing and was suspected to be unmated after producing no eggs during days 1-4 in the presence of *Ehretia* (*acuminata*?) leaves from the Bunya Mts., Q. On day 5 a bouquet of *Cynoglossum australe* was added. During the next 4 nights she produced 38 eggs, all laid singly on the *Cynoglossum*, none on *Ehretia*. Most were deposited on unopened flower buds or in sepal cups containing young nutlets (60%), although an appreciable number were placed on undersides of leaves (29%); the remaining few were on leaf uppersides and stems. Most were nested in crevices around buds, where they were sometimes piled up, or among plant hairs, in the fashion characteristic of many Nearctic *Ethmia* (Powell, 1971).

*Egg.*—Eggs (fig. 4) were similar in shape and surface sculpture to Holarctic *Ethmia*, resembling those of *E. postica* in size, shape, and color. Chorion characteristics indicate closer relationship to *E. heptasema*, with a system of irregular cuneiform, rather than oval or rectangular segments. Eggs ranged 0.63-0.75 X 0.33-0.41 mm in length and diameter, varying with placement. Development was rapid, hatching occurring in fewer than 6 days.

*Larva.*—Newly emerged larvae failed to feed on buds, nutlets, or leaves of 6-day old *Cynoglossum australe* and escaped from a faulty container before other plant material could be provided.

Failure of *Ehretia* to elicit oviposition, together with the precise selection of hirsute *Cynoglossum* buds suggests some Boraginaceae other than *Ehretia* is the normal host plant, despite the fact that most collection records are from rain forest localities.

*Collection data.*—Mt. Tamborine, Q., 10 Jan. 1981 (MV) (JAP 81A114).

*Ethmia heptasema* (Turner, 1898)

This species differs markedly in genital characters from any other in the Australian fauna. According to genital structures, it appears to be most closely related to *E. heliomela*, a supposition enhanced by the oviposition behavior of the two. *E. heptasema* occurs in rain forests of coastal mountains from central Queensland to the Illawarra District, N. S. W., and there are possibly conspecific specimens from New Guinea (Powell, 1982).

*Adult behavior*.—The moths are nocturnal. Most collections have been made at lights, and *E. heptasema* has the largest eyes of any Australian *Ethmia*, with an eye index above 1.0, indicative of nocturnal behavior in Nearctic species (Powell, 1973: 8). Four females were confined in 2 petri dishes during a 15 day period in mid-January. Leaves of *Ehretia* (*acuminata*?) from the Bunya Mts., Q. were provided. About 250 eggs were produced, and females exhibited different preferences for oviposition sites. In one dish one or both moths deposited 28 eggs, 26 of them in axils of the raised underside leaf veins where they nested against small tangles of plant hairs (fig. 5). In the second dish the females deposited 222 eggs, mostly on leaf edges (57%) or in the damp cotton wick (36%). A few were placed on glass sides of the container, none on leaf vein axils.

Although a few eggs were isolated singly in each dish, most were deposited in small, irregularly assembled clusters of 3-9 eggs. Egg clutches placed in leaf vein axils ranged 1-4 per site ( $\bar{x} = 2.4$ , 11n) (fig. 5); those on leaf margins often were aggregated into larger clusters, often composed of eggs of different ages, indicating retn visits to the sites on successive days. Isolated clutches of uniform age on leaf margins and container walls consisted of 2-9 eggs ( $\bar{x} = 4.5$ , 8n). Females displayed selection preference for aggregation of eggs once a cluster was started, with most of the available leaf margins remaining unused. As many as 10-13 eggs may have been deposited at once in the larger batches, judging from age groups.

*Eggs*.—Individual eggs were cylindrical, resembling typical Holarctic *Ethmia* eggs in shape but not chorion sculpture, which was an intricate system of cuneiform segments (fig. 6). Those in clusters varied in form with placement. Eggs of *E. heptasema* were unusually small; isolated eggs ranged 0.57-0.62 X 0.35-0.38 mm in length and diameter. Differing stages of development were easily detected because the white eggs turned yellow within 24 hrs, then reddish orange by 48-72 hrs and began to show mandibular spots within 110 hrs. Hatching occurred in fewer than 6 days despite intermittent transport in a field ice box.

*Larva*.—Newly hatched larvae were provided with mature *Ehretia* leaves which were beginning to deteriorate after storage 5-8 days without consistent refrigeration. The final larvae to emerge were placed on fresh *Cynoglossum australe*, but no feeding took place on either plant.

Nonetheless, the geographical distribution of *Ethmia heptasema*, the



strong oviposition response to *Ehretia*, and the precise selection of sites on the leaves, suggests that *Ehretia acuminata* is the normal hostplant. Possibly mature leaves pose physical barriers to feeding by first instar larvae, and buds or new leaves are requisite to larval establishment.

*Collection data.*—Mt. Tamborine, Q., 4 Jan. 1981 (MV, b1) (JAP 81A103).

*Ethmia heliomela* Lower, 1923

*Ethmia heliomela* is a small, brightly colored moth unlike any other Australian ethmiid. By structural features it appears to be related to *E. lapidella* (Walsingham) of India and the Orient, a species that superficially resembles *E. heptasema*. *Ethmia lapidella* has been reported to feed on *Ehretia dicksoni* var *japonica* Nakai and "soongroo (wild *Salvia*)" (Fabaceae?) (Fletcher, 1920: 133; Sattler, 1967). The latter record may have been based on a misidentified plant or a wandering full grown larva. *E. heliomela* is known only from eastern montane and coastal rain forests, from southern Queensland to southern N. S. W.

*Adult behavior.*—The orange and black hindwings and abdomen and relatively small eyes (eye index 0.90-0.95), give this species the appearance of a diurnal moth. The adults commonly fly to lights, however, so it is presumed to be primarily nocturnal. I found adults perched on *Ehretia* foliage in late afternoon and early morning. Under laboratory conditions, activity consistently took place during afternoon hours, but neither mating nor oviposition was observed. A freshly emerged male and female were caged in mid-November, but they survived only two days in unseasonably warm weather. Dissection showed the female unmated (80L38). Five females collected from foliage of *Ehretia acuminata* were individually confined in 42 X 60 mm plastic vials with branchlets of *Ehretia* inflorescences in bud to early bloom. These moths survived only 2-5 days. Two females deposited 11 and 23 eggs, either singly (62%) or in pairs or clusters of 3 or 4; usually laid side by side. All were placed on walls of the containers.

*Egg.*—The eggs resembled those of *E. heptasema* (fig. 6) in shape and chorion sculpture viewed at 50X magnification. They measured 0.61-0.65 x 0.35 mm at the rectangulate-oval base of attachment and were ca. 0.25-0.30 mm thick. During development the eggs turned pale yellow within 12 hrs, then pink within 48 hrs. Hatching occurred in ca. 10 days.

*Larva.*—No attempt was made to feed newly hatched larvae, but caterpillars of the penultimate and at least 2 preceding instars were found in conspicuous webs in inflorescences of *Ehretia*. Quite small larvae produced copious silk networks encompassing branchlets several cm apart. Sometimes 2 larvae occupied one web, but they were not colonial, living individually except where abundant. At Mt. Keira only in the final 2 instars were larvae found to feed on leaves, usually by extending webbing

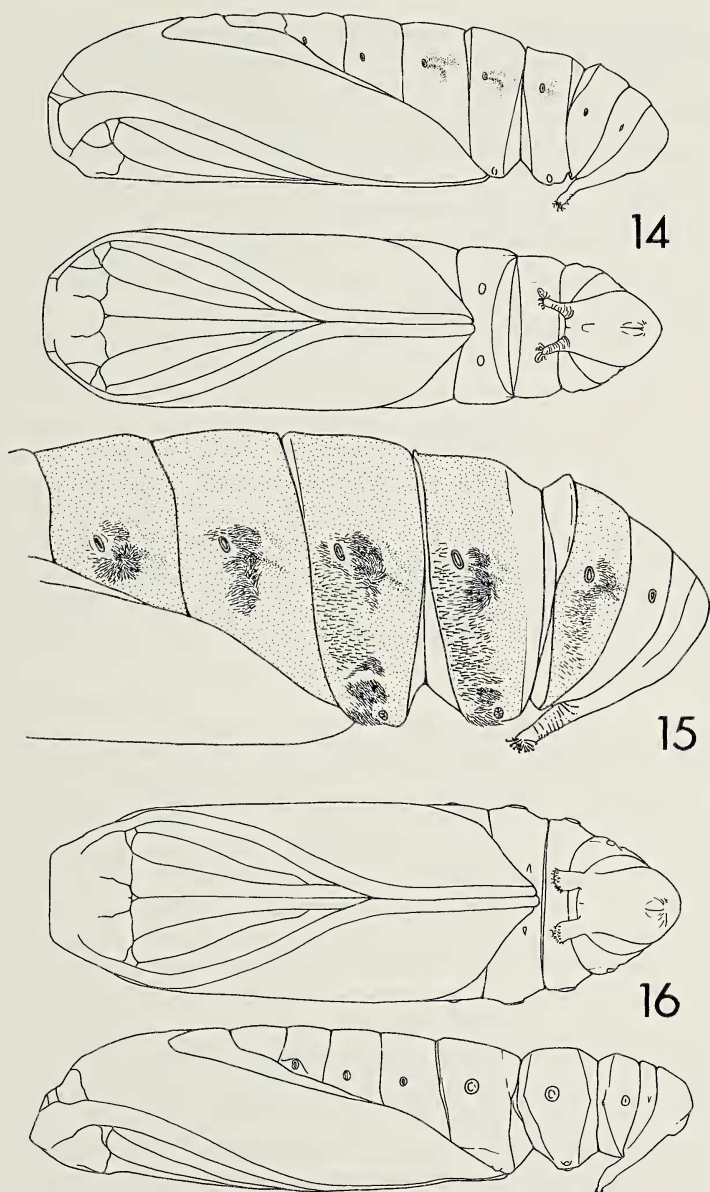
from wilted inflorescences onto subtending leaves where they skeletonized the upper surface. Timing of oviposition seemed to be related to that of flowering; young larvae were collected November 26 from trees in bud to early bloom, but another tree with buds just starting to develop had none. Three weeks later David Walsh observed webbing and larvae on the latter tree and on Dec. 22 I found larvae of the final 3 instars on its inflorescences in late bloom. In the laboratory late instar larvae fed on leaves after inflorescence material had been consumed.

*Final instar larva.*—Length 15.8-16.8 mm (5n). *Head:* HC width 1.22-1.26 mm. Setation as typical for genus (e.g. MacKay, 1972). Adfrontal sutures reaching cervical angle, adfrontal areas abruptly narrowed posteriorly. Black to dark amber brown, conspicuously contrasting pale bands flanking adfrontals and longitudinally on venter, beneath stemmatal area. Primary setal arrangements of thorax and abdomen as in fig. 9. Prothorax with strongly delineated shield, black narrowly edged with amber to mostly amber blotched with blackish; 5 secondary setae along its anterior margin on each side; D1 and D2 widely separated. Sclerotized depressions associated with spiracles or with prothoracic legs absent. L2 tiny on A1-8. Secondary setae absent except a row of 6 or 7 anterior to SV on A9. Color pattern variable, mostly dark olive green (appearing black on living caterpillars), as in fig. 9, with pale bands narrowly at mid-dorsum and of irregular spots longitudinally in SD, L areas (tan or pale greenish in life); a separate color phase has the dark markings restricted, lacking from posterior  $\frac{1}{2}$  or  $\frac{1}{3}$  of each segment so that the larva has segmental, transverse pale bands. Pinacula sclerotized, dark brown, darker above spiracles. Crochets of abdominal prolegs uniordinal but varying in size, 30-34 in a circle, of anal prolegs, 34.

The larval color phases appeared to be discrete, without a gradation of intermediates, in the last instar, but they could not be separated in early instars. Penultimate and antepenultimate instars were similarly patterned to the fgl but were paler. The banded form, segregated as a subplot (80M30.1), produced normal *E. heliomela* adults. One larva, perhaps teneral, was observed that appeared orange with pale cream longitudinal bands to the unaided eye. It too was separated (80M30.2) and produced *E. heliomela*.

Evidently this species is capable of developing dense population levels, during which larval feeding is not restricted to inflorescences. Larval webbing encompassed an entire *Ehretia* tree near Jamberoo, N. S. W. in May 1980 according to D. S. Stevens (*in litt.* to I. F. B. Common). His photographs show strings of larvae festooning the defoliated tree. It is possible that other Lepidoptera were involved, but only *E. heliomela* was reared, from cocoons in the bark of a silk-covered piece of a large branch.

I did not discover a pupation site in the field but in or under loose bark may be normal. In the laboratory cocoons were plastered onto paper



Figs. 14-16. Pupal characters of Australian *Ethmia*: 14, *E. nigroapicella* pupa, lateral (upper) and ventral (lower) aspects; 15, *E. nigroapicella*, detail of abdominal sculpture and setation; 16, *E. heliomela* pupa, lateral (upper) and ventral (lower) aspects.



towelling incorporating debris, on paper under flat cardboard or in lumens of corrugated cardboard, and once in a curled dry leaf.

*Pupa* (fig. 16).—Length 6.8-7.6 mm (5n). Head truncate, square-margined ventrally. Antennae and wings extending beyond A4, nearly across A5. Intersegmental areas preceding A6 and A7 deeply cleft dorsally and ventrally, movable by lateral condyles. No setaceous areas. Spiracles of A5, A6 huge, ca. 2X diameter of those on A2-4 and 7; A8 sp absent. Anal legs well developed, variable in shape, separation, and angle of projection; bearing a series of short hooked spurs distally. A10 without setae representing the true cremaster.

The enlarged spiracles of segments 5-6 and loss of spiracle on 8 are unique among described Ethmiidae and perhaps all Lepidoptera. According to Mosher (1916: 29) spiracles are always present on abdominal segments 1-8 in Lepidoptera, although those of the 8th are never functional and show no distinct opening.

Under laboratory conditions development time of pupae varied. Although feeding ceased within 10 days, emergences occurred 18-30 days following collection of larvae in both November and December, and continued sporadically up to 80 days. Material collected at Jamberoo in May produced adults in August and again in November, indicating that diapause occurs in the pupa and termination is facultative in response to environmental cues, as is known in Holarctic *Ethmia* (Powell, 1973: 40; 1974).

*Voltinism*.—Collections of adults indicate a flight period from October to February, but 80% of the records are in spring, primarily November and early December. In New South Wales, only 3 (12%) of the collections were made in January and February, suggesting that a summer generation is facultative and relatively rare, as indicated by sporadic emergences in laboratory conditions. At Mt. Keira, in 1980 I collected both adults and larvae in late November and again 4 weeks later but could find neither in early February. Thus it is likely that *E. heliomela* normally undergoes two generations in spring and early summer and occasionally emerges later, particularly if *Ehretia* blooms sporadically and the moth's ovipositor is cued to the same factors that influence inflorescence development.

*Natural enemies*.—Although many larvae were collected, most of those not preserved became diseased prior to maturing, probably the result of suboptimal conditions in the lab. Among 17 individuals reared to maturity, only one was parasitized. A tachinid emerged within 23 days of the larval collection after pupation inside a *heliomela* cocoon, before pupation of the host larva.

*Collection data*.—Jamberoo, N. S. W. May 1980 (D. S. Stevens), adults emgd. Nov. 1980 (JAP80L38); Mt. Keira, Wollongong, N. S. W., 25/26 Nov. 1980, adults (80L46), larvae (80L47) on *Ehretia acuminata*; same data 22 Dec. 1980 (80M30).

*Acknowledgments.* In addition to helping with some of the collections, I. F. B. Common provided much of the background knowledge necessary for the study, as well as hospitality and facilities during my visit. Grateful thanks are also extended to D. F. Waterhouse, former Chief, and to other staff members of the Division of Entomology for assistance with transportation and facilities, making possible the fieldwork and other aspects of the study. SEM photos of the eggs were made by Barry Filshie, of eggshells by J. A. DeBenedictis, U. C. Berkeley. Carolyn Millinex Tibbetts, U. C. Berkeley, made the drawings of pupal characters and inked my drafts of setal maps of the larvae.

Assembly of specimen data and mapping of distributions were carried out by Elizabeth Randal. Cooperation by Lesley Lockwood and authorities of the National Botanic Garden and Herbarium Australiense, CSIRO enabled use of living plant samples and of collections in their care.

David Walsh, caretaker of the Mt. Keira Boy Scout Camp, Wollongong, N. S. W., provided facilities and botanic expertise making possible several collections that were critical to the study. Discoveries of ethmiids at Mt. Keira and elsewhere by Victor J. Robinson provided much of the background information for my taxonomic and biological work.

K. T. Richards, Dept. of Agriculture, Perth, W. A., loaned larval and pupal specimens of *Ethmia hemadelpha*, and F. G. Howarth and G. M. Nishida, Dept. Entomology, Bernice P. Bishop Museum, Honolulu, provided pupal shells of *E. nigroapicella*, enabling inclusion of their descriptions.

## Literature Cited

- COMMON, I. F. B., 1954. A study of the ecology of the adult bogong moth, *Agrotis infusa* (Boisd.) (Lepidoptera: Noctuidae), with special reference to its behaviour during migration and aestivation. *Austral. J. Zool.*, 2:223-263.
- , 1970. Lepidoptera (Moths and Butterflies) in *Insects of Australia*; pp. 765-866. Melbourne; Melbourne U. Press.
- DIAKONOFF, A., 1967. Microlepidoptera of the Philippine Islands. *U. S. Natl. Mus., Bull.* 257; 284 pp.
- FLETCHER, T. B., 1933. Life histories of Indian Microlepidoptera (Second Series). Cosmopterigidae to Neopseustidae. *Imp. Counc. Agric. Research, Sci. Monogr.*, No. 4; 85 pp.
- FOX, K. J., 1978. The transoceanic migration of Lepidoptera to New Zealand—A history and a hypothesis on colonization. *N. Z. Entomol.*, 6:368-379.
- HODGES, R. W., 1978. Gelechioidea. Cosmopterigidae. *in: Moths N. A. North of Mexico*; fasc. 6.1; 166 pp. + 6 pl. E. W. Classey and Wedge Entomol. Research Found.; London.
- KUZNETSOV, V. I. & A. A. STEKOL'NIKOV, 1979. The systematic position and phylogenetic relationships of the superfamily Coleophoroidea (Lepidoptera: Oecophoridae, Coleophoridae, Ethmiidae) as revealed by the functional morphology of the male genitalia. *Entomol. Review*, 57(1):91-103.
- LEGRAND, H., 1965. Lepidopteres des Iles Seychelles et de l'Aldabra. *Mem. Mus. Nat. Hist. Natl., Paris Ser. A. (Zool.)*, 37:1-210.
- MAKAY, M. R., 1972. Larval sketches of some microlepidoptera, chiefly North American. *Entomol. Soc. Canad., Mem.* 88; 83 pp. 1978 *in* Zimmerman, *Insects*

- of Hawaii. Vol. 9(2) Microlepidoptera; fig. 643. U. Press Hawaii; Honolulu.
- McFARLAND, N., 1979. Annotated list of larval foodplant records for 280 species of Australian moths. J. Lepid. Soc., 33, suppl; 72 pp.
- MORIUTI, S., 1963. Ethmiidae from the Amami-Gunto Islands, Southern Frontier of Japan, collected by Mr. T. Kodama in 1960. Butterfl. Moths, 14:35-39.
- MOSHER, E., 1916. A classification of the Lepidoptera based on characters of the pupa. Bull. Ill. St. Lab. Nat. Hist., 12:17-159, pl. 19-27.
- POWELL, J. A., 1971. Biological studies on moths of the genus *Ethmia* in California (Gelechioidea). J. Lepid. Soc., 25, Suppl. 3; 67 pp.
- \_\_\_\_\_, 1973. A systematic monograph of New World ethmiid moths (Lepidoptera: Gelechioidea). Smithson. Contr. Zool., 120; 302 pp.
- \_\_\_\_\_, 1974. Occurrence of prolonged diapause in ethmiid moths (Lepidoptera: Gelechioidea). Pan-Pacific Entomol., 50:220-225.
- \_\_\_\_\_, 1980. Evolution of larval food preferences in microlepidoptera. Ann. Rev. Entomol., 25:133-159.
- \_\_\_\_\_, 1982. Taxonomy and geographical relationships of Australian ethmiid moths (Lepidoptera: Gelechioidea). in review for Austral. J. Zool.
- SATTLER, K., 1967. Ethmiidae. Microlep. Palaeart., 2; Textband 185 pp.; Tafelband, 106 plates. Verlag. G. Fromme & Co., Vienna.
- SWEZEY, O. H., 1944. The Kou moth, *Ethmia colonella* Walsm., in Hawaii. Proc. Hawaiian Ent. Soc., 12(1943):133-135.
- ZIMMERMAN, E. C., 1978. Insects of Hawaii. Vol. 9, 1936 pp. U. Hawaii Press, Honolulu.